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Begin Translation:

CLAIMS

[Claim 1] Vibration removal equipment characterized by providing the following. Shock absorbing desk. The air spring which supports the aforementioned shock absorbing desk. The air valve which adjusts the pressure of the aforementioned air spring. The displacement sensor which measures the variation rate of the aforementioned shock absorbing desk and the aforementioned air spring, and the displacement target generation machine which outputs the desired value over the variation rate of the aforementioned shock absorbing desk and the aforementioned air spring, The displacement compensator which compensates the difference signal of the output signal of the aforementioned displacement target generation machine, and the output signal of the aforementioned displacement sensor, and controls the variation rate of the aforementioned shock absorbing desk and the aforementioned air spring, the output signal of the acceleration sensor which measures vibration of the aforementioned shock absorbing desk, and the aforementioned acceleration sensor -- compensation -- giving -- the above -- a variation rate -- with the acceleration compensator which carries out negative feedback of the acceleration of the aforementioned shock absorbing desk to the input side of a compensator The pressure sensor which measures the pressure of the aforementioned air spring, and the pressure target generation machine which outputs the desired value over the pressure of the aforementioned air spring, The pressure compensator which compensates the composite signal of the output signal of the aforementioned displacement compensator and the aforementioned pressure target generation machine, and the output signal of the aforementioned pressure sensor, and controls the pressure of the aforementioned air spring, The rigid compensator which are the power amplifier which drives the aforementioned air valve according to the output signal of the aforementioned pressure compensator, and a rigid compensator which has a low cut filter and a proportional gain element, and compensates the output signal of the aforementioned displacement sensor, carries out negative feedback to the input side of the aforementioned pressure compensator, and controls the rigidity of an air spring.
[Claim 2] The device manufacturing installation characterized by having vibration removal equipment according to claim 1.
[Claim 3] The device manufacture method characterized by manufacturing a device using a device manufacturing installation according to claim 2.

DETAILED DESCRIPTION

[0001]
[The technical field to which invention belongs] this invention relates to the vibration removal equipment which reduces the oscillating transfer from the equipment installation foundation in precision mechanical equipments, such as an aligner used for manufacture of liquid crystal devices, such as semiconductor devices, such as IC, LSI, and CCD, and a liquid crystal panel.

[0002]
[Description of the Prior Art] Highly efficient-ization of the precision vibration removal equipment which carries them is called for with highly-precise-izing of precision mechanical equipments, such as an electron microscope and semiconductor fabrication machines and equipment. In order to make suitable and quick exposure perform especially in semiconductor fabrication machines and equipment, the vibration removal equipment which eliminates vibration transmitted from the outside, such as installation floor vibration, as much as possible is required. It is because the X-Y stage for exposure will have to be in the state of a drop dead halt in case a semiconductor wafer is exposed in semiconductor fabrication machines and equipment. Moreover, since the X-Y stage for exposure is characterized by intermittent control action called step-and-repeat, step movement of a repeat excites the own vibration of a shock absorbing desk. Therefore, vibration removal equipment is asked for realizing the vibration removal performance to extraneous vibration, and the damping performance to vibration generated by own operation of a loading device with sufficient balance.

[0003] To such a demand, vibration of a shock absorbing desk is measured by the sway sensor, and the vibration removal equipment of the so-called active method which drives a shock absorbing desk with an actuator according to the measurement signal is put in practical use. It is common to use an air spring as an actuator with the vibration removal equipment of an active method. An air spring is because sufficient thrust to support a heavy lift like semiconductor fabrication machines and equipment can be generated easily. The composition of the typical vibration removal equipment seen by the conventional technology is shown in drawing 5 .

[0004] Operation of the vibration removal equipment seen by the conventional technology shown in drawing 5 is explained. Surfacing support of the shock absorbing desk 1 which carries precision mechanical equipments, such as an X-Y stage for exposure, is carried out from the installation floor 100 by the air spring 5. By carrying out surfacing support of the shock absorbing desk 1 with an air spring 5, vibration isolation of the shock absorbing desk 1 can be carried out from the installation floor 100. The pressure of an air spring 5 is adjusted by the air valve 4. An air valve 4 has the common nozzle-flapper type equipped with 3 of the air-supply port 61, the exhaust air port 62, and the output-pressure port 63 ports as shown in drawing 6 . An output pressure changes according to the amount of air valve drives (flapper opening). The property of the amount of air valve drives and an output pressure is shown in drawing 7 . Like drawing 7 , an amount of air valve drives-output-pressure property has a hysteresis on a nonlinear target, and is strong. [of nonlinearity] Moreover, generally, a response is slow and the self-regulation of an air spring of a pressure is bad. Then, feedback control of a pressure is performed in many cases as the pressure of an air spring 5 is

measured and the amount of air valve drives is adjusted according to the measurement signal, when adjusting the pressure of an air spring 5 using an air valve 4.

[0005] In drawing 5 , a pressure sensor 3 measures the pressure of an air spring 5. The pressure target generation machine 11 outputs the desired value over the pressure of the steady state to which the air spring 5 carried out surfacing support of the shock absorbing desk 1. A pressure compensator 12 performs compensation whose output signal of a pressure sensor 3 corresponds to the sum of the output signal of the displacement compensator 9 mentioned later and the acceleration compensator 10, and the output signal of the pressure target generation machine 11. A power amplifier 13 supplies power to an air valve 4 according to the output of a pressure compensator 11, and drives an air valve 4. The pressure of an air spring 5 is controlled by feedback control of such a pressure to a desired value.

[0006] Moreover, a displacement sensor 2 measures the variation rate of a shock absorbing desk 1 and an air spring 5. a variation rate -- the target generation machine 7 -- surfacing of a shock absorbing desk 1 and an air spring 5 -- the desired value over a variation rate is outputted The displacement compensator 9 performs compensation to which the difference of the output signal of the displacement target generation machine 7 and the output signal of a displacement sensor 2 serves as zero. this -- surfacing of a shock absorbing desk 1 and an air spring 5 -- a variation rate is held uniformly An acceleration sensor 6 measures vibration of a shock absorbing desk 1. The acceleration compensator 10 compensates the output signal of an acceleration sensor 6, and forms the negative feedback system of acceleration. Vibration generated in a shock absorbing desk 1 by this is suppressed.

[0007]

[Problem(s) to be Solved by the Invention] With the vibration removal equipment using the air spring, in order to improve the self-regulation of an amendment sake and the pressure of an air spring for the nonlinear characteristic of an air valve, feedback control of the so-called pressure which measures the pressure of an air spring by the pressure sensor, and drives an air valve according to the output signal is performed. However, when feedback control of a pressure was performed to the air spring, there was a trouble that the rigidity of an air spring will fall and vibration of a shock absorbing desk will increase. The shock absorbing desk in which an air spring carries out surfacing support balances in the state where the gravity and the bearing power from an air spring which act on a shock absorbing desk are in agreement. The bearing power from an air spring multiplies the effective area of diaphragm in the contact section of an air spring and a shock absorbing desk by the pressure of an air spring, and becomes settled. Since the capacity of an air spring changes according to the variation rate of a shock absorbing desk and the pressure of an air spring originally changes when vibration occurs in a shock absorbing desk for some disturbance force, such as drive reaction force of the X-Y stage for exposure laid in a shock absorbing desk in semiconductor fabrication machines and equipment, the stability to the equilibrium proportional to a variation rate which returns a shock absorbing desk to equilibrium acts on a shock absorbing desk from an air spring. This is the rigidity of an air spring. Since it functions as the feedback control of a pressure holding the pressure of an air spring uniformly, even if capacity change of the variation rate of a shock absorbing desk and an air spring arises, the pressure of an air spring does

not change. That is, the rigidity of an air spring falls and the stability to equilibrium does not act on a shock absorbing desk. Therefore, when feedback control of a pressure was performed and vibration occurred by some factors, such as disturbance force, in a shock absorbing desk, since it was the reduction of rigidity of an air spring, there was a problem that vibration of a shock absorbing desk will increase. In conventional vibration removal equipment, what has solved the reduction of rigidity of the air spring by the feedback control of a pressure cannot be seen.

[0008] this invention is made in consideration of such a situation. That is, the purpose of this invention is to offer the vibration removal equipment which can perform feedback control of the pressure of an air spring, without causing the reduction of rigidity of an air spring.

[0009]

[Means for Solving the Problem] In order to attain the above-mentioned purpose, the vibration removal equipment by this invention A shock absorbing desk, the air spring which supports the aforementioned shock absorbing desk, and the air valve which adjusts the pressure of the aforementioned air spring, The pressure sensor which measures the pressure of the aforementioned air spring, and the displacement sensor which measures the variation rate of the aforementioned shock absorbing desk, and the variation rate of the aforementioned air spring, The acceleration sensor which measures vibration of the aforementioned shock absorbing desk, and the acceleration compensator which compensates the output signal of the aforementioned acceleration sensor and forms the negative feedback system of acceleration, The displacement target generation machine which outputs the desired value over the variation rate of the aforementioned shock absorbing desk and the aforementioned air spring, The displacement compensator which compensates the difference signal of the output signal of the aforementioned displacement target generation machine, and the output signal of the aforementioned displacement sensor, and controls the variation rate of the aforementioned shock absorbing desk and the aforementioned air spring, The rigid compensator which is a rigid compensator which has a low cut filter and a proportional gain element, and compensates the output signal of the aforementioned displacement sensor and controls the rigidity of an air spring, The pressure compensator which compensates the output signal of the pressure target generation machine which outputs the desired value over the pressure of the aforementioned air spring, the aforementioned acceleration compensator and the aforementioned displacement compensator, the aforementioned rigid compensator, and the aforementioned pressure target generation machine, and the output signal of the aforementioned pressure sensor, and controls the pressure of the aforementioned air spring, It is characterized by having the power amplifier which drives the aforementioned air valve according to the output signal of the aforementioned pressure compensator.

[0010] Moreover, the device manufacturing installation by this invention is characterized by having the aforementioned vibration removal equipment. As a device manufacturing installation, there are semiconductor fabrication machines and equipment for manufacturing semiconductor chips, such as IC and LSI, etc.

[0011]

[Function] An air spring carries out surfacing support of the shock absorbing desk which carries precision mechanical equipments, such as an X-Y stage for exposure. An air valve adjusts the pressure of an air spring. A pressure sensor

measures the pressure of an air spring. A pressure target generation machine outputs the desired value over the pressure of the steady state to which the air spring carried out surfacing support of the shock absorbing desk. A pressure compensator performs compensation whose output signal of a pressure sensor corresponds to the sum of the output signal of a rigid compensator, a displacement compensator, and an acceleration compensator, and the output signal of a pressure target generation machine. A power amplifier supplies power to an air valve according to the output of a pressure compensator, and drives an air valve.
[0012] a displacement sensor -- the variation rate of a shock absorbing desk, and surfacing of an air spring -- a variation rate is measured A displacement target generation machine outputs the desired value over the variation rate of a shock absorbing desk, and the variation rate of an air spring. A displacement compensator performs compensation to which the difference of the output signal of a displacement target generation machine and the output signal of a displacement sensor serves as zero so that a shock absorbing desk may orientate to a desired surfacing position. It is fixed to the shock absorbing desk and an acceleration sensor measures vibration produced in a shock absorbing desk as an acceleration signal. An acceleration compensator compensates the output signal of an acceleration sensor, and forms the negative feedback of acceleration. This gives damping to a shock absorbing desk.
[0013] The rigid compensator which has a low cut filter and a proportional gain element compensates the output signal of a displacement sensor so that rigidity may be given to a shock absorbing desk and an air spring. The shock absorbing desk in which an air spring carries out surfacing support balances in the state where the gravity and the bearing power from an air spring which act on a shock absorbing desk are in agreement. When vibration occurs in a shock absorbing desk for some disturbance force, such as drive reaction force of the X-Y stage for exposure laid in a shock absorbing desk in semiconductor fabrication machines and equipment, a rigid compensator functions as the stability to the equilibrium which is proportional to the variation rate of a shock absorbing desk or the variation rate of an air spring through the air spring which is an actuator acting to a shock absorbing desk.
[0014] Thus, even if it performs feedback control of a pressure, the reduction of rigidity of an air spring is not produced by the function of a rigid compensator. The feedback control of a pressure rectifies the nonlinear characteristic of an air valve, and improves the self-regulation of the pressure of an air spring. Simultaneously, since the reduction of rigidity of an air spring is not produced, vibration removal equipment with a good oscillating suppression performance is realizable.
[0015]
[Example] The example of the vibration removal equipment by this invention is explained in detail based on a drawing. <u>Drawing 1</u> shows the composition of the vibration removal equipment concerning one example of this invention. In this drawing, surfacing support of the shock absorbing desk 1 is carried out by the air spring 5. While it is a support saddle which carries out surfacing support of the shock absorbing desk 1, an air spring 5 is also the actuator on which damping force is made to act to a shock absorbing desk 1 by the pressure variation of an air spring 5 in order to suppress vibration of a shock absorbing desk 1. The pressure of an air spring 5 is adjusted by the air valve 4.
[0016] Feedback control of a pressure is realized as follows. A pressure sensor 3 measures the pressure of an air spring 5. The pressure target generation machine

11 outputs the desired value over the pressure of the steady state to which the air spring 5 carried out surfacing support of the shock absorbing desk 1. A pressure compensator 12 performs compensation whose output signal of a pressure sensor 3 corresponds to the sum of the output signal of the rigid compensator 8 mentioned later, the displacement compensator 9, and the acceleration compensator 10, and the output signal of the pressure target generation machine 11. A power amplifier 13 supplies power to an air valve 4 according to the output of a pressure compensator 11, and drives an air valve 4. The pressure of an air spring 5 is controlled by feedback control of such a pressure to a desired value.
[0017] A displacement sensor 2 measures the variation rate of a shock absorbing desk 1, and the variation rate of an air spring 5. The variation rate of the air spring 5 here is the stroke of an air spring 5, and it is the same as that of the variation rate of a shock absorbing desk 1. a variation rate -- the target generation machine 7 -- the variation rate of a shock absorbing desk 1, and surfacing of an air spring 5 -- the desired value over a variation rate is outputted The displacement compensator 9 performs compensation to which the difference of the output signal of the displacement target generation machine 7 and the output signal of a displacement sensor 2 serves as zero so that a shock absorbing desk 1 may orientate to a desired surfacing position. A stock-in-trade designs the displacement compensator 9 so that the pressure of an air spring 5 may be controlled by integration of the input signal. It is for making it converge promptly, without overshooting the variation rate of a shock absorbing desk 1 to the output signal of the displacement target generation machine 7.
[0018] It is fixed to the shock absorbing desk 1, and an acceleration sensor 5 measures vibration produced in a shock absorbing desk 1 as an acceleration signal. The acceleration compensator 10 compensates the output signal of an acceleration sensor 6, and forms the negative feedback of acceleration. If the acceleration compensator 10 generates the compensation value proportional to the output of an acceleration sensor 6 and inputs this compensation value into the displacement compensator 9, the damping force proportional to the integration of acceleration, i.e., speed, can be made to act on a shock absorbing desk 1, since the displacement compensator 9 is designed so that the pressure of an air spring 5 may be controlled by integration of the input signal as mentioned above. Damping was given to the shock absorbing desk 1 by this, and vibration produced in a shock absorbing desk 1 is suppressed effectively.
[0019] The rigid compensator 8 which has a low cut filter 14 and the proportional gain element 15 compensates the output signal of a displacement sensor 2 so that rigidity may be given to a shock absorbing desk 1 and an air spring 5. The shock absorbing desk 1 in which an air spring 5 carries out surfacing support balances in the state where the gravity and the bearing power from an air spring 5 which act on a shock absorbing desk 1 are in agreement. When vibration occurs in a shock absorbing desk 1 for some disturbance force, such as drive reaction force of the X-Y stage for exposure laid in a shock absorbing desk 1 in semiconductor fabrication machines and equipment, the rigid compensator 8 functions as the stability to the equilibrium which is proportional to the variation rate of a shock absorbing desk 1 or the variation rate of an air spring 5 through the air spring 5 which is an actuator acting to a shock absorbing desk 1. By this, rigidity was given to the shock absorbing desk 1 and the air spring 5, and vibration produced in a shock absorbing desk 1 is suppressed effectively.
[0020] Although the rigid compensator 8 and the displacement compensator 9 are

both considering the signal of a displacement sensor 2 as the input, as explained until now, both functions completely differ. The rigid compensator 8 functions as making the stability to the equilibrium proportional to the variation rate of a shock absorbing desk 1, or the variation rate of an air spring 5 act to a shock absorbing desk 1. The reduction of rigidity of the air spring 5 by feedback of the pressure mentioned above is avoidable with this. The displacement compensator 9 functions as the force acting to a shock absorbing desk 1 by the integration of the difference of the output signal of the displacement target generation machine 7, and the output signal of a displacement sensor 2 so that it may orientate without a shock absorbing desk 1 overshooting to a desired surfacing position. Therefore, the function of the displacement compensator 9 cannot give rigidity to an air spring 5. Rigidity is because it is the thing of the stability to the equilibrium proportional to the variation rate.

[0021] Hereafter, operation of the rigid compensator 8 is explained in more detail. Drawing 2 shows the dynamics model of the portion which consists of a shock absorbing desk 1, an air valve 4, and an air spring 5. A shock absorbing desk 1 can be modeled as a mass element of mass mu. The effective area of diaphragm of a portion in which f and a shock absorbing desk 1 receive the force for the disturbance force of acting the variation rate on x and a shock absorbing desk 1 from an air spring 5 is set to A. An air valve 4 adjusts the inflow outflow discharge of air, and the pressure p of an air spring 5 according to the amount u of air valve drives. (1) formula is obtained about movement of a shock absorbing desk 1 from drawing 2 noting that a pressure p is the amount of change from equilibrium. Moreover, (2) formulas are materialized about the pressure of an air spring 5.

[0022]

[Equation 1]

$$M\frac{d^2}{dt^2}x = Ap + f \qquad (1)$$

$$\frac{d}{dt}p + \omega p = G_q\ u - G_v\frac{d}{dt}x \qquad (2)$$

[0023] (2) In a formula, the coefficient omega concerning the pressure p of left part is physical quantity which becomes settled from the mechanical parameter of an air spring 5. Moreover, coefficient Gq concerning the amount u of air valve drives of the right-hand side It is the pressure gain of an air valve 4. Similarly, the term which contains the variation rate x of a shock absorbing desk 1 by the right-hand side means that the pressure p of an air spring 5 changes with the variation rate x, and is Gv. It is the influence coefficient. (1) By carrying out the Laplace transform of a formula and the (2) formulas, the block diagram of drawing 3 having shown the dynamics model of drawing 2 mathematically is obtained. In drawing 3 , Sign s expresses the Laplacian operator. From drawing 3 , the I/O formula which inputted the amount u of air valve drives and the disturbance force f, and inputted the output the variation rate x of a shock absorbing desk 1 becomes like (3) formulas. (3) In the formula, AGv s/(second+omega) of left part expresses the rigidity of an air spring 5.

[0024]

[Equation 2]

$$\left(Ms^2 + AG_v\frac{s}{s+\omega}\right)x = f + \frac{1}{s+\omega}AG_q\ u \qquad (3)$$

[0025] The block diagram having shown mathematically operation of the vibration removal equipment by this example is drawing 4 . Only enough elements which need drawing 4 to explain operation of the rigid compensator 8 are shown, and other components, such as the displacement compensator 9 and the acceleration compensator 10, are omitted. In drawing 4 , a pressure compensator 12 is a proportionality computing element, and sets the gain to G. Moreover, it is Gk about the transfer function of the rigid compensator 8. It carries out. The I/O formula of drawing 4 which inputted the disturbance force f and inputted the output the variation rate x of a shock absorbing desk 1 is as (4) formulas.

[0026]

[Equation 3]

$$\left(Ms^2 + AG_v \frac{s}{s+\omega+G_q\ G} + AG_v \frac{1}{s+\omega+G_q\ G} \frac{G_q\ GG_k}{G_v}\right) x = f \qquad (4)$$

[0027] Supposing there is no rigid compensator 8 and it is Gk =0, the I/O formula of (4) formulas will become like (5) formulas. In this case, although the rigid term showing the rigidity of an air spring 5 is AGv s/(second+omega+Gq G) from the left part of (5) formulas, since the gain G of a pressure compensator 12 is in the denominator of a rigid term, as for a rigid term, Gain G becomes small, so that it is large. That is, (5) formulas show that the rigidity of an air spring 5 falls, so that gain G of the feedback loop of a pressure is enlarged.

[0028]

[Equation 4]

$$\left(Ms^2 + AG_v \frac{s}{s+\omega+G_q\ G}\right) x = f \qquad (5)$$

[0029] The rigid compensator 8 functions as avoiding the reduction of rigidity of the air spring 5 by the feedback control of a pressure. (4) As shown in a formula, the rigid term of an air spring 5 is AGv s/(second+omega+Gq G)+AGv/(second+omega+Gq G) xGq GGk/Gv by operation of the rigid compensator 8. It has become. Namely, transfer function Gk of the rigid compensator 8 Since a rigid term also becomes large so that it takes greatly, rigidity required for an air spring 5 is securable. Transfer function Gk What is necessary is just to specifically design as follows. First, when not performing feedback control of a pressure, the rigid term of an air spring 5 was AGv s/(second+omega) from (3) formula left part. Transfer function Gk It designs so that the rigid term of (4) formulas which are an I/O formula of the vibration removal equipment by this invention may be in agreement with this. (3) If a formula is compared with (4) formulas, it will be the transfer function Gk of the rigid compensator 8. It becomes settled like (6) formulas.

[0030]

[Equation 5]

$$G_k = \frac{s}{s+\omega} \frac{G_v\ (\omega+G_q\ G)}{G_q\ G} \qquad (6)$$

[0031] (6) Transfer function Gk defined by the formula (7) formulas will be obtained if it substitutes for (4) formulas which are an I/O formula of the vibration removal equipment by this example. (7) The left part of a formula and the left part of (3) formulas which are an I/O formula when not performing feedback control of a pressure are completely the same. It turns out that the rigidity of the completely

same air spring 5 as the case where feedback control of a pressure is not performed is securable with operation of the rigid compensator 8. Moreover, transfer function Gk of the rigid compensator 8 shown by (6) formulas Transfer function s/showing a low cut filter (second+omega) It consists of series connections with proportional gain Gv/(omega+Gq G) Gq G. The vibration removal equipment by this example is characterized by the rigid compensator 8 having a low cut filter 14 and the proportional gain element 15.
[0032]
[Equation 6]

$$\left(Ms^2 + AG_V \frac{s}{s+\omega}\right)x = f \qquad (7)$$

[0033] Thus, since the reduction of rigidity of an air spring 5 is avoidable with operation of the rigid compensator 8, the vibration removal equipment by this example has realized the suitable oscillating suppression performance. In addition, the vibration removal equipment by this invention is not limited to the operation form shown in drawing 1 . Essence of this invention that it is vibration removal equipment which can perform feedback control of the pressure of an air spring, without producing the reduction of rigidity of an air spring can be carried out regardless of the number of an air spring, arrangement, etc. which support the configuration of a shock absorbing desk, and it. Moreover, the semiconductor fabrication machines and equipment which have vibration removal equipment by this invention are realizable also in driven type and scan type any serially.
[0034] The formula sign used until now is packed into a degree, and is listed.
M: mass A: of a shock absorbing desk 1 -- effective-area-of-diaphragm x: of an air spring 5 -- variation-rate p: of a shock absorbing desk 1 -- amount of pressure u:air valve drives f: of an air spring 5 -- disturbance force omega: which acts on a shock absorbing desk 1 -- transfer function of the physical quantity Gq rigidity compensator 8 which becomes settled from the mechanical parameter of an air spring 5 : Pressure gain Gv of an air valve 4 : influence-coefficient G: to the pressure p of the variation rate x of a shock absorbing desk 1 to the air spring 5 -- gain
[The example of a device process] Next, the example of the process of the device using the aligner which has vibration removal equipment which gave [above-mentioned] explanation is explained. Drawing 8 shows the flow of manufacture of minute devices (semiconductor chips, such as IC and LSI, a liquid crystal panel, CCD, the thin film magnetic head, micro machine, etc.). The pattern design of a device is performed at Step 1 (circuit design). The mask in which the designed pattern was formed is manufactured at Step 2 (mask manufacture). On the other hand, at Step 3 (wafer manufacture), a wafer is manufactured using material, such as silicon and glass. Step 4 (wafer process) is called last process, and forms an actual circuit on a wafer with lithography technology using the mask and wafer which carried out [above-mentioned] preparation. The following step 5 (assembly) is called back process, is a process semiconductor-chip-ized using the wafer produced by Step 4, and includes processes, such as an assembly process (dicing, bonding) and a packaging process (chip enclosure). At Step 6 (inspection), the check test of the semiconductor device produced at Step 5 of operation, an endurance test, etc. are inspected. A semiconductor device is completed through such a process and this is shipped (Step 7).
[0036] Drawing 9 shows the detailed flow of the above-mentioned wafer process.

The front face of a wafer is oxidized at Step 11 (oxidization). An insulator layer is formed in a wafer front face at Step 12 (CVD). At Step 13 (electrode formation), an electrode is formed by vacuum evaporationo on a wafer. Ion is driven into a wafer at Step 14 (ion implantation). A sensitization agent is applied to a wafer at Step 15 (resist processing). At Step 16 (exposure), printing exposure of the circuit pattern of a mask is carried out by the aligner which has vibration removal equipment which gave [above-mentioned] explanation at a wafer. The exposed wafer is developed at Step 17 (development). At Step 18 (etching), portions other than the developed resist image are shaved off. The resist which etching could be managed with Step 19 (resist exfoliation), and became unnecessary is removed. By carrying out by repeating these steps, a circuit pattern is formed on a wafer multiplex. If the process of this example is used, the highly-integrated device for which manufacture was difficult can be conventionally manufactured to a low cost.
[0037]
[Effect of the Invention] As explained above, according to this invention, the vibration removal equipment which can perform feedback control of the pressure of an air spring, without reducing the rigidity of an air spring can be offered. In the vibration removal equipment by this invention, the feedback control of a pressure rectifies the nonlinear characteristic of an air valve, and the self-regulation of the pressure of an air spring is improved. Since the reduction of rigidity of the air spring which had become a problem with the conventional technology is not produced simultaneously, a suitable oscillating suppression performance is realizable.

TECHNICAL FIELD

[The technical field to which invention belongs] this invention relates to the vibration removal equipment which reduces the oscillating transfer from the equipment installation foundation in precision mechanical equipments, such as an aligner used for manufacture of liquid crystal devices, such as semiconductor devices, such as IC, LSI, and CCD, and a liquid crystal panel.

PRIOR ART

[Description of the Prior Art] Highly efficient-ization of the precision vibration removal equipment which carries them is called for with highly-precise-izing of precision mechanical equipments, such as an electron microscope and semiconductor fabrication machines and equipment. In order to make suitable and quick exposure perform especially in semiconductor fabrication machines and equipment, the vibration removal equipment which eliminates vibration transmitted from the outside, such as installation floor vibration, as much as possible is required. It is because the X-Y stage for exposure will have to be in the state of a drop dead halt in case a semiconductor wafer is exposed in semiconductor fabrication machines and equipment. Moreover, since the X-Y stage for exposure is characterized by intermittent control action called step-and-repeat, step movement of a repeat excites the own vibration of a shock absorbing desk. Therefore, vibration removal equipment is asked for realizing the vibration removal performance to extraneous vibration, and the damping performance to vibration generated by own operation of a loading device with sufficient balance.
[0003] To such a demand, vibration of a shock absorbing desk is measured by the sway sensor, and the vibration removal equipment of the so-called active method

which drives a shock absorbing desk with an actuator according to the measurement signal is put in practical use. It is common to use an air spring as an actuator with the vibration removal equipment of an active method. An air spring is because sufficient thrust to support a heavy lift like semiconductor fabrication machines and equipment can be generated easily. The composition of the typical vibration removal equipment seen by the conventional technology is shown in drawing 5 .

[0004] Operation of the vibration removal equipment seen by the conventional technology shown in drawing 5 is explained. Surfacing support of the shock absorbing desk 1 which carries precision mechanical equipments, such as an X-Y stage for exposure, is carried out from the installation floor 100 by the air spring 5. By carrying out surfacing support of the shock absorbing desk 1 with an air spring 5, vibration isolation of the shock absorbing desk 1 can be carried out from the installation floor 100. The pressure of an air spring 5 is adjusted by the air valve 4. An air valve 4 has the common nozzle-flapper type equipped with 3 of the air-supply port 61, the exhaust air port 62, and the output-pressure port 63 ports as shown in drawing 6 . An output pressure changes according to the amount of air valve drives (flapper opening). The property of the amount of air valve drives and an output pressure is shown in drawing 7 . Like drawing 7 , an amount of air valve drives-output-pressure property has a hysteresis on a nonlinear target, and is strong. [of nonlinearity] Moreover, generally, a response is slow and the self-regulation of an air spring of a pressure is bad. Then, feedback control of a pressure is performed in many cases as the pressure of an air spring 5 is measured and the amount of air valve drives is adjusted according to the measurement signal, when adjusting the pressure of an air spring 5 using an air valve 4.

[0005] In drawing 5 , a pressure sensor 3 measures the pressure of an air spring 5. The pressure target generation machine 11 outputs the desired value over the pressure of the steady state to which the air spring 5 carried out surfacing support of the shock absorbing desk 1. A pressure compensator 12 performs compensation whose output signal of a pressure sensor 3 corresponds to the sum of the output signal of the displacement compensator 9 mentioned later and the acceleration compensator 10, and the output signal of the pressure target generation machine 11. A power amplifier 13 supplies power to an air valve 4 according to the output of a pressure compensator 11, and drives an air valve 4. The pressure of an air spring 5 is controlled by feedback control of such a pressure to a desired value.

[0006] Moreover, a displacement sensor 2 measures the variation rate of a shock absorbing desk 1 and an air spring 5. a variation rate -- the target generation machine 7 -- surfacing of a shock absorbing desk 1 and an air spring 5 -- the desired value over a variation rate is outputted The displacement compensator 9 performs compensation to which the difference of the output signal of the displacement target generation machine 7 and the output signal of a displacement sensor 2 serves as zero. this -- surfacing of a shock absorbing desk 1 and an air spring 5 -- a variation rate is held uniformly An acceleration sensor 6 measures vibration of a shock absorbing desk 1. The acceleration compensator 10 compensates the output signal of an acceleration sensor 6, and forms the negative feedback system of acceleration. Vibration generated in a shock absorbing desk 1 by this is suppressed.

EFFECT OF THE INVENTION

As explained above, according to this invention, the vibration removal equipment which can perform feedback control of the pressure of an air spring, without reducing the rigidity of an air spring can be offered. In the vibration removal equipment by this invention, the feedback control of a pressure rectifies the nonlinear characteristic of an air valve, and the self-regulation of the pressure of an air spring is improved. Since the reduction of rigidity of the air spring which had become a problem with the conventional technology is not produced simultaneously, a suitable oscillating suppression performance is realizable.

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] With the vibration removal equipment using the air spring, in order to improve the self-regulation of an amendment sake and the pressure of an air spring for the nonlinear characteristic of an air valve, feedback control of the so-called pressure which measures the pressure of an air spring by the pressure sensor, and drives an air valve according to the output signal is performed. However, when feedback control of a pressure was performed to the air spring, there was a trouble that the rigidity of an air spring will fall and vibration of a shock absorbing desk will increase. The shock absorbing desk in which an air spring carries out surfacing support balances in the state where the gravity and the bearing power from an air spring which act on a shock absorbing desk are in agreement. The bearing power from an air spring multiplies the effective area of diaphragm in the contact section of an air spring and a shock absorbing desk by the pressure of an air spring, and becomes settled. Since the capacity of an air spring changes according to the variation rate of a shock absorbing desk and the pressure of an air spring originally changes when vibration occurs in a shock absorbing desk for some disturbance force, such as drive reaction force of the X-Y stage for exposure laid in a shock absorbing desk in semiconductor fabrication machines and equipment, the stability to the equilibrium proportional to a variation rate which returns a shock absorbing desk to equilibrium acts on a shock absorbing desk from an air spring. This is the rigidity of an air spring. Since it functions as the feedback control of a pressure holding the pressure of an air spring uniformly, even if capacity change of the variation rate of a shock absorbing desk and an air spring arises, the pressure of an air spring does not change. That is, the rigidity of an air spring falls and the stability to equilibrium does not act on a shock absorbing desk. Therefore, when feedback control of a pressure was performed and vibration occurred by some factors, such as disturbance force, in a shock absorbing desk, since it was the reduction of rigidity of an air spring, there was a problem that vibration of a shock absorbing desk will increase. In conventional vibration removal equipment, what has solved the reduction of rigidity of the air spring by the feedback control of a pressure cannot be seen.

[0008] this invention is made in consideration of such a situation. That is, the purpose of this invention is to offer the vibration removal equipment which can perform feedback control of the pressure of an air spring, without causing the reduction of rigidity of an air spring.

MEANS

[Means for Solving the Problem] In order to attain the above-mentioned purpose, the vibration removal equipment by this invention A shock absorbing desk, the air spring which supports the aforementioned shock absorbing desk, and the air valve which adjusts the pressure of the aforementioned air spring, The pressure sensor which measures the pressure of the aforementioned air spring, and the displacement sensor which measures the variation rate of the aforementioned shock absorbing desk, and the variation rate of the aforementioned air spring, The acceleration sensor which measures vibration of the aforementioned shock absorbing desk, and the acceleration compensator which compensates the output signal of the aforementioned acceleration sensor and forms the negative feedback system of acceleration, The displacement target generation machine which outputs the desired value over the variation rate of the aforementioned shock absorbing desk and the aforementioned air spring, The displacement compensator which compensates the difference signal of the output signal of the aforementioned displacement target generation machine, and the output signal of the aforementioned displacement sensor, and controls the variation rate of the aforementioned shock absorbing desk and the aforementioned air spring, The rigid compensator which is a rigid compensator which has a low cut filter and a proportional gain element, and compensates the output signal of the aforementioned displacement sensor and controls the rigidity of an air spring, The pressure compensator which compensates the output signal of the pressure target generation machine which outputs the desired value over the pressure of the aforementioned air spring, the aforementioned acceleration compensator and the aforementioned displacement compensator, the aforementioned rigid compensator, and the aforementioned pressure target generation machine, and the output signal of the aforementioned pressure sensor, and controls the pressure of the aforementioned air spring, It is characterized by having the power amplifier which drives the aforementioned air valve according to the output signal of the aforementioned pressure compensator.
[0010] Moreover, the device manufacturing installation by this invention is characterized by having the aforementioned vibration removal equipment. As a device manufacturing installation, there are semiconductor fabrication machines and equipment for manufacturing semiconductor chips, such as IC and LSI, etc.

OPERATION

[Function] An air spring carries out surfacing support of the shock absorbing desk which carries precision mechanical equipments, such as an X-Y stage for exposure. An air valve adjusts the pressure of an air spring. A pressure sensor measures the pressure of an air spring. A pressure target generation machine outputs the desired value over the pressure of the steady state to which the air spring carried out surfacing support of the shock absorbing desk. A pressure compensator performs compensation whose output signal of a pressure sensor corresponds to the sum of the output signal of a rigid compensator, a displacement compensator, and an acceleration compensator, and the output signal of a pressure target generation machine. A power amplifier supplies power to an air valve according to the output of a pressure compensator, and drives an air valve.
[0012] a displacement sensor -- the variation rate of a shock absorbing desk, and

surfacing of an air spring -- a variation rate is measured A displacement target generation machine outputs the desired value over the variation rate of a shock absorbing desk, and the variation rate of an air spring. A displacement compensator performs compensation to which the difference of the output signal of a displacement target generation machine and the output signal of a displacement sensor serves as zero so that a shock absorbing desk may orientate to a desired surfacing position. It is fixed to the shock absorbing desk and an acceleration sensor measures vibration produced in a shock absorbing desk as an acceleration signal. An acceleration compensator compensates the output signal of an acceleration sensor, and forms the negative feedback of acceleration. This gives dumping to a shock absorbing desk.

[0013] The rigid compensator which has a low cut filter and a proportional gain element compensates the output signal of a displacement sensor so that rigidity may be given to a shock absorbing desk and an air spring. The shock absorbing desk in which an air spring carries out surfacing support balances in the state where the gravity and the bearing power from an air spring which act on a shock absorbing desk are in agreement. When vibration occurs in a shock absorbing desk for some disturbance force, such as drive reaction force of the X-Y stage for exposure laid in a shock absorbing desk in semiconductor fabrication machines and equipment, a rigid compensator functions as the stability to the equilibrium which is proportional to the variation rate of a shock absorbing desk or the variation rate of an air spring through the air spring which is an actuator acting to a shock absorbing desk.

[0014] Thus, even if it performs feedback control of a pressure, the reduction of rigidity of an air spring is not produced by the function of a rigid compensator. The feedback control of a pressure rectifies the nonlinear characteristic of an air valve, and improves the self-regulation of the pressure of an air spring. Simultaneously, since the reduction of rigidity of an air spring is not produced, vibration removal equipment with a good oscillating suppression performance is realizable.

EXAMPLE

The example of the vibration removal equipment by this invention is explained in detail based on a drawing. Drawing 1 shows the composition of the vibration removal equipment concerning one example of this invention. In this drawing, surfacing support of the shock absorbing desk 1 is carried out by the air spring 5. While it is a support saddle which carries out surfacing support of the shock absorbing desk 1, an air spring 5 is also the actuator on which damping force is made to act to a shock absorbing desk 1 by the pressure variation of an air spring 5 in order to suppress vibration of a shock absorbing desk 1. The pressure of an air spring 5 is adjusted by the air valve 4.

[0016] Feedback control of a pressure is realized as follows. A pressure sensor 3 measures the pressure of an air spring 5. The pressure target generation machine 11 outputs the desired value over the pressure of the steady state to which the air spring 5 carried out surfacing support of the shock absorbing desk 1. A pressure compensator 12 performs compensation whose output signal of a pressure sensor 3 corresponds to the sum of the output signal of the rigid compensator 8 mentioned later, the displacement compensator 9, and the acceleration compensator 10, and the output signal of the pressure target generation machine 11. A power amplifier 13 supplies power to an air valve 4 according to the output of a pressure

compensator 11, and drives an air valve 4. The pressure of an air spring 5 is controlled by feedback control of such a pressure to a desired value.

[0017] A displacement sensor 2 measures the variation rate of a shock absorbing desk 1, and the variation rate of an air spring 5. The variation rate of the air spring 5 here is the stroke of an air spring 5, and it is the same as that of the variation rate of a shock absorbing desk 1. a variation rate -- the target generation machine 7 -- the variation rate of a shock absorbing desk 1, and surfacing of an air spring 5 -- the desired value over a variation rate is outputted The displacement compensator 9 performs compensation to which the difference of the output signal of the displacement target generation machine 7 and the output signal of a displacement sensor 2 serves as zero so that a shock absorbing desk 1 may orientate to a desired surfacing position. A stock-in-trade designs the displacement compensator 9 so that the pressure of an air spring 5 may be controlled by integration of the input signal. It is for making it converge promptly, without overshooting the variation rate of a shock absorbing desk 1 to the output signal of the displacement target generation machine 7.

[0018] It is fixed to the shock absorbing desk 1, and an acceleration sensor 5 measures vibration produced in a shock absorbing desk 1 as an acceleration signal. The acceleration compensator 10 compensates the output signal of an acceleration sensor 6, and forms the negative feedback of acceleration. If the acceleration compensator 10 generates the compensation value proportional to the output of an acceleration sensor 6 and inputs this compensation value into the displacement compensator 9, the damping force proportional to the integration of acceleration, i.e., speed, can be made to act on a shock absorbing desk 1, since the displacement compensator 9 is designed so that the pressure of an air spring 5 may be controlled by integration of the input signal as mentioned above. Damping was given to the shock absorbing desk 1 by this, and vibration produced in a shock absorbing desk 1 is suppressed effectively.

[0019] The rigid compensator 8 which has a low cut filter 14 and the proportional gain element 15 compensates the output signal of a displacement sensor 2 so that rigidity may be given to a shock absorbing desk 1 and an air spring 5. The shock absorbing desk 1 in which an air spring 5 carries out surfacing support balances in the state where the gravity and the bearing power from an air spring 5 which act on a shock absorbing desk 1 are in agreement. When vibration occurs in a shock absorbing desk 1 for some disturbance force, such as drive reaction force of the X-Y stage for exposure laid in a shock absorbing desk 1 in semiconductor fabrication machines and equipment, the rigid compensator 8 functions as the stability to the equilibrium which is proportional to the variation rate of a shock absorbing desk 1 or the variation rate of an air spring 5 through the air spring 5 which is an actuator acting to a shock absorbing desk 1. By this, rigidity was given to the shock absorbing desk 1 and the air spring 5, and vibration produced in a shock absorbing desk 1 is suppressed effectively.

[0020] Although the rigid compensator 8 and the displacement compensator 9 are both considering the signal of a displacement sensor 2 as the input, as explained until now, both functions completely differ. The rigid compensator 8 functions as making the stability to the equilibrium proportional to the variation rate of a shock absorbing desk 1, or the variation rate of an air spring 5 act to a shock absorbing desk 1. The reduction of rigidity of the air spring 5 by feedback of the pressure mentioned above is avoidable with this. The displacement compensator 9 functions as the force acting to a shock absorbing desk 1 by the integration of the difference

of the output signal of the displacement target generation machine 7, and the output signal of a displacement sensor 2 so that it may orientate without a shock absorbing desk 1 overshooting to a desired surfacing position. Therefore, the function of the displacement compensator 9 cannot give rigidity to an air spring 5. Rigidity is because it is the thing of the stability to the equilibrium proportional to the variation rate.

[0021] Hereafter, operation of the rigid compensator 8 is explained in more detail. Drawing 2 shows the dynamics model of the portion which consists of a shock absorbing desk 1, an air valve 4, and an air spring 5. A shock absorbing desk 1 can be modeled as a mass element of mass mu. The effective area of diaphragm of a portion in which f and a shock absorbing desk 1 receive the force for the disturbance force of acting the variation rate on x and a shock absorbing desk 1 from an air spring 5 is set to A. An air valve 4 adjusts the inflow outflow discharge of air, and the pressure p of an air spring 5 according to the amount u of air valve drives. (1) formula is obtained about movement of a shock absorbing desk 1 from drawing 2 noting that a pressure p is the amount of change from equilibrium. Moreover, (2) formulas are materialized about the pressure of an air spring 5.

[0022]

[Equation 1]

$$M\frac{d^2}{dt^2}x = Ap + f \qquad (1)$$

$$\frac{d}{dt}p + \omega p = G_q\ u - G_v\frac{d}{dt}x \qquad (2)$$

[0023] (2) In a formula, the coefficient omega concerning the pressure p of left part is physical quantity which becomes settled from the mechanical parameter of an air spring 5. Moreover, coefficient Gq concerning the amount u of air valve drives of the right-hand side It is the pressure gain of an air valve 4. Similarly, the term which contains the variation rate x of a shock absorbing desk 1 by the right-hand side means that the pressure p of an air spring 5 changes with the variation rate x, and is Gv. It is the influence coefficient. (1) By carrying out the Laplace transform of a formula and the (2) formulas, the block diagram of drawing 3 having shown the dynamics model of drawing 2 mathematically is obtained. In drawing 3 , Sign s expresses the Laplacian operator. From drawing 3 , the I/O formula which inputted the amount u of air valve drives and the disturbance force f, and inputted the output the variation rate x of a shock absorbing desk 1 becomes like (3) formulas. (3) In the formula, AGv s/(second+omega) of left part expresses the rigidity of an air spring 5.

[0024]

[Equation 2]

$$\left(Ms^2 + AG_v\frac{s}{s+\omega}\right)x = f + \frac{1}{s+\omega}AG_q\ u \qquad (3)$$

[0025] The block diagram having shown mathematically operation of the vibration removal equipment by this example is drawing 4 . Only enough elements which need drawing 4 to explain operation of the rigid compensator 8 are shown, and other components, such as the displacement compensator 9 and the acceleration compensator 10, are omitted. In drawing 4 , a pressure compensator 12 is a proportionality computing element, and sets the gain to G. Moreover, it is Gk about the transfer function of the rigid compensator 8. It carries out. The I/O formula of

drawing 4 which inputted the disturbance force f and inputted the output the variation rate x of a shock absorbing desk 1 is as (4) formulas.
[0026]
[Equation 3]

$$\left(Ms^2 + AG_v \frac{s}{s+\omega+G_q\ G} + AG_v \frac{1}{s+\omega+G_q\ G} \frac{G_q\ GG_k}{G_v}\right) x = f \qquad (4)$$

[0027] Supposing there is no rigid compensator 8 and it is Gk =0, the I/O formula of (4) formulas will become like (5) formulas. In this case, although the rigid term showing the rigidity of an air spring 5 is AGv s/(second+omega+Gq G) from the left part of (5) formulas, since the gain G of a pressure compensator 12 is in the denominator of a rigid term, as for a rigid term, Gain G becomes small, so that it is large. That is, (5) formulas show that the rigidity of an air spring 5 falls, so that gain G of the feedback loop of a pressure is enlarged.
[0028]
[Equation 4]

$$\left(Ms^2 + AG_v \frac{s}{s+\omega+G_q\ G}\right) x = f \qquad (5)$$

[0029] The rigid compensator 8 functions as avoiding the reduction of rigidity of the air spring 5 by the feedback control of a pressure. (4) As shown in a formula, the rigid term of an air spring 5 is AGv s/(second+omega+Gq G)+AGv/(second+omega+Gq G) xGq GGk/Gv by operation of the rigid compensator 8. It has become. Namely, transfer function Gk of the rigid compensator 8 Since a rigid term also becomes large so that it takes greatly, rigidity required for an air spring 5 is securable. Transfer function Gk What is necessary is just to specifically design as follows. First, when not performing feedback control of a pressure, the rigid term of an air spring 5 was AGv s/(second+omega) from (3) formula left part. Transfer function Gk It designs so that the rigid term of (4) formulas which are an I/O formula of the vibration removal equipment by this invention may be in agreement with this. (3) If a formula is compared with (4) formulas, it will be the transfer function Gk of the rigid compensator 8. It becomes settled like (6) formulas.
[0030]
[Equation 5]

$$G_k = \frac{s}{s+\omega} \frac{G_v\ (\omega+G_q\ G)}{G_q\ G} \qquad (6)$$

[0031] (6) Transfer function Gk defined by the formula (7) formulas will be obtained if it substitutes for (4) formulas which are an I/O formula of the vibration removal equipment by this example. (7) The left part of a formula and the left part of (3) formulas which are an I/O formula when not performing feedback control of a pressure are completely the same. It turns out that the rigidity of the completely same air spring 5 as the case where feedback control of a pressure is not performed is securable with operation of the rigid compensator 8. Moreover, transfer function Gk of the rigid compensator 8 shown by (6) formulas Transfer function s/showing a low cut filter (second+omega) It consists of series connections with proportional gain Gv/(omega+Gq G) Gq G. The vibration removal equipment by this example is characterized by the rigid compensator 8 having a low cut filter 14 and the proportional gain element 15.

[0032]
[Equation 6]

$$\left(Ms^2 + AG_V \frac{s}{s+\omega}\right)x = f \qquad (7)$$

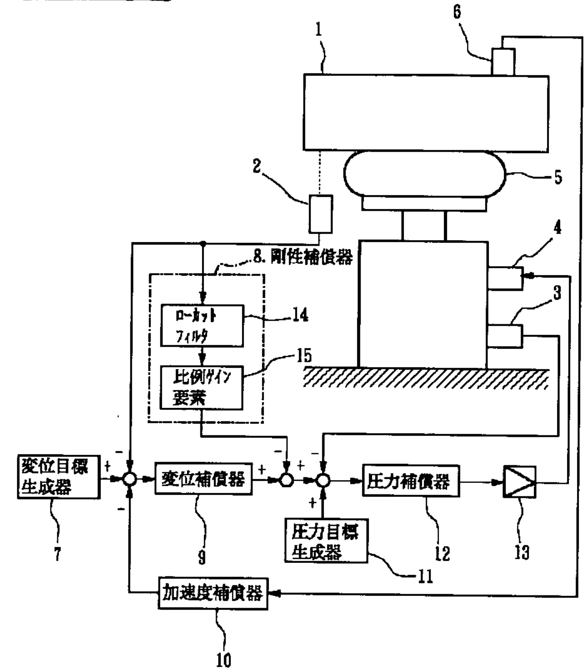
[0033] Thus, since the reduction of rigidity of an air spring 5 is avoidable with operation of the rigid compensator 8, the vibration removal equipment by this example has realized the suitable oscillating suppression performance. In addition, the vibration removal equipment by this invention is not limited to the operation gestalt shown in drawing 1 . Essence of this invention that it is vibration removal equipment which can perform feedback control of the pressure of an air spring, without producing the reduction of rigidity of an air spring can be carried out regardless of the number of an air spring, arrangement, etc. which support the configuration of a shock absorbing desk, and it. Moreover, the semiconductor fabrication machines and equipment which have vibration removal equipment by this invention are realizable also in driven type and scan type any serially.
[0034] The formula sign used until now is packed into a degree, and is listed. M: mass A: of a shock absorbing desk 1 -- effective-area-of-diaphragm x: of an air spring 5 -- variation-rate p: of a shock absorbing desk 1 -- amount of pressure u:air valve drives f: of an air spring 5 -- disturbance force omega: which acts on a shock absorbing desk 1 -- the physical quantity Gq which becomes settled from the mechanical parameter of an air spring 5 : Pressure gain Gv of an air valve 4 : influence-coefficient G: to the pressure p of the variation rate x of a shock absorbing desk 1 to the air spring 5 -- gain Gk in case a pressure compensator 12

DESCRIPTION OF DRAWINGS

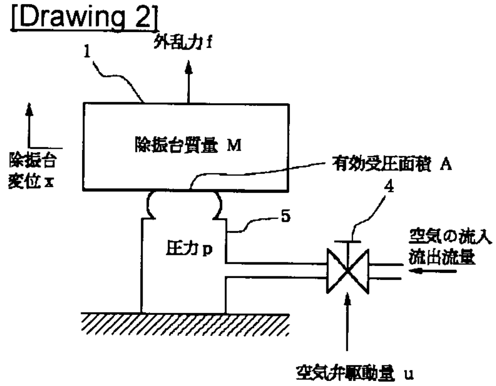
[Brief Description of the Drawings]
[Drawing 1] It is the block diagram of the vibration removal equipment concerning one example of this invention.
[Drawing 2] It is the drawing in which the dynamics model of a shock absorbing desk and an air spring is shown.
[Drawing 3] It is the drawing in which the dynamics model of a shock absorbing desk and an air spring is shown mathematically.
[Drawing 4] It is the drawing in which operation of the vibration removal equipment by this invention is shown mathematically.
[Drawing 5] It is the drawing in which the vibration removal equipment by the conventional technology is shown.
[Drawing 6] It is the drawing in which the structure of an air valve is shown.
[Drawing 7] It is the drawing in which the property of an air valve is shown.
[Drawing 8] It is drawing showing the flow of manufacture of a minute device.
[Drawing 9] It is drawing showing the detailed flow of the wafer process in drawing 8 .
[Description of Notations]
1: A shock absorbing desk, 2:displacement sensor, 3:pressure sensor, 4:air valve, 5:air spring, 6:acceleration sensor, 7:displacement target generation machine, 8:rigidity compensator, 9 : a displacement compensator, 10 : An acceleration compensator, 11 : A pressure target generation machine, 12 : A pressure compensator, 13:power amplifier, 14:low cut filter, 15: Proportional gain element.

DRAWINGS

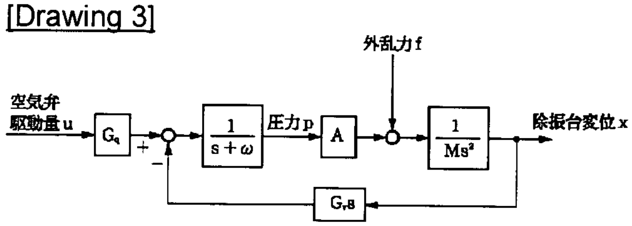
[Drawing 1]



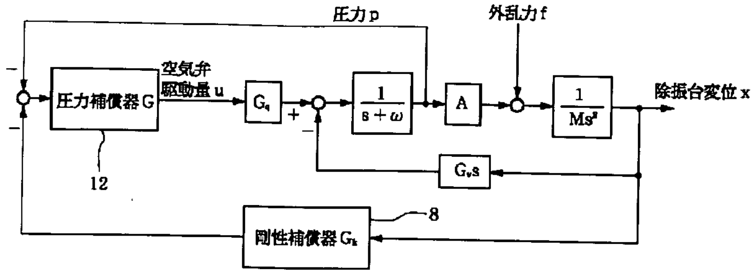
[Drawing 2]



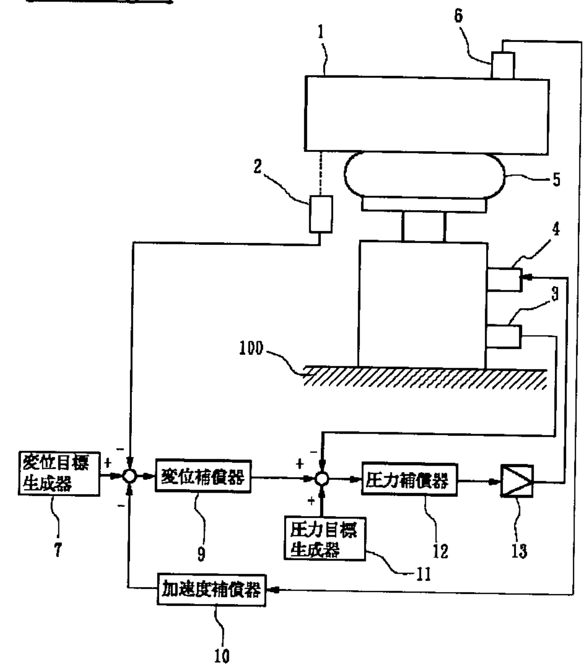
[Drawing 3]



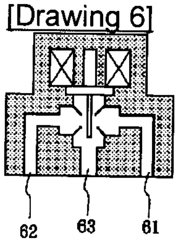
[Drawing 4]



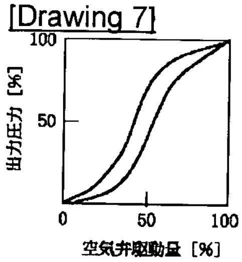
[Drawing 5]



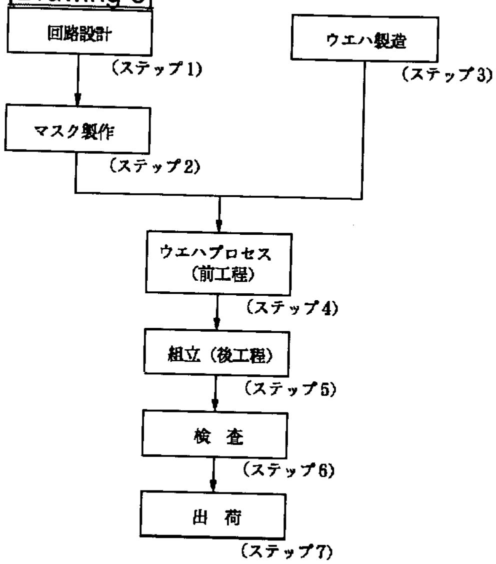
[Drawing 6]



[Drawing 7]

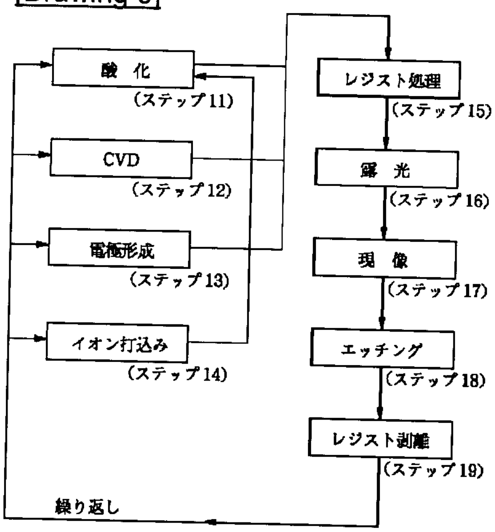


[Drawing 8]



半導体デバイス製造フロー

[Drawing 9]



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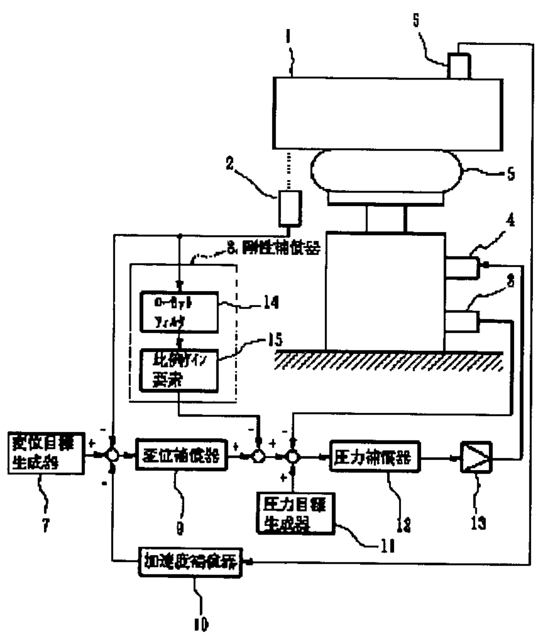
最終頁に続く

(54)【発明の名称】　除振装置

(57)【要約】　　（修正有）

【課題】　空気ばねの圧力のフィードバック制御を行なう。

【解決手段】　除振台１および空気ばね５の変位に対する目標値を出力する変位目標生成器７の出力信号と変位センサ２の出力信号との差信号に補償を施し除振台および空気ばねの変位を制御する変位補償器９と、加速度センサ６の出力信号に補償を施して変位補償器の入力側に除振台の加速度を負帰還する加速度補償器１０と、空気ばねの圧力に対する目標値を出力する圧力目標生成器１１と、変位補償器および圧力目標生成器の出力信号と圧力センサの出力信号との合成信号に補償を施し空気ばねの圧力を制御する圧力補償器１２の出力信号に応じて空気弁を駆動するパワー増幅器１３とを有する除振装置において、ローカットフィルタと比例ゲイン要素を有し、変位センサの出力信号に補償を施して圧力補償器１２の入力側に負帰還する剛性補償器８を設けることにより、空気ばねの剛性を制御する。



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【特許請求の範囲】

【請求項１】　除振台と、

前記除振台を支持する空気ばねと、

前記空気ばねの圧力を調整する空気弁と、

前記除振台および前記空気ばねの変位を計測する変位センサと、

前記除振台および前記空気ばねの変位に対する目標値を出力する変位目標生成器と、

前記変位目標生成器の出力信号と前記変位センサの出力信号との差信号に補償を施し前記除振台および前記空気ばねの変位を制御する変位補償器と、

前記除振台の振動を計測する加速度センサと、

前記加速度センサの出力信号に補償を施して前記変位補償器の入力側に前記除振台の加速度を負帰還する加速度補償器と、

前記空気ばねの圧力を計測する圧力センサと、

前記空気ばねの圧力に対する目標値を出力する圧力目標生成器と、

前記変位補償器および前記圧力目標生成器の出力信号と前記圧力センサの出力信号との合成信号に補償を施し前記空気ばねの圧力を制御する圧力補償器と、

前記圧力補償器の出力信号に応じて前記空気弁を駆動するパワー増幅器と、

ローカットフィルタと比例ゲイン要素を有する剛性補償器であり、かつ、前記変位センサの出力信号に補償を施し前記圧力補償器の入力側に負帰還して空気ばねの剛性を制御する剛性補償器とを有することを特徴とする除振装置。

【請求項２】　請求項１に記載の除振装置を有することを特徴とするデバイス製造装置。

【請求項３】　請求項２に記載のデバイス製造装置を用いてデバイスを製造することを特徴とするデバイス製造方法。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、ＩＣ、ＬＳＩ、ＣＣＤ等の半導体デバイスや液晶パネル等の液晶デバイスの製造に用いられる露光装置等の精密機器において、装置設置基礎からの振動伝達を低減する除振装置に関する。

【０００２】

【従来の技術】電子顕微鏡、半導体製造装置等の精密機器の高精度化に伴い、それらを搭載する精密除振装置の高性能化が求められている。特に半導体製造装置においては適切かつ迅速な露光を行なわせるために、設置床振動など外部から伝達する振動を極力排除する除振装置が必要である。半導体製造装置では半導体ウエハを露光する際に露光用ＸＹステージが完全停止の状態になければならないからである。また露光用ＸＹステージはステップアンドリピートという間欠動作を特徴としているために、繰り返しのステップ運動が除振台自身の振動を励起する。したがって除振装置には、外部振動に対する除振性能と、搭載機器自身の動作により発生する振動に対する制振性能とをバランスよく実現することが求められる。

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【０００３】このような要求に対して、除振台の振動を振動センサで計測し、その計測信号に応じてアクチュエータで除振台を駆動する、いわゆるアクティブ方式の除振装置が実用化されている。アクティブ方式の除振装置ではアクチュエータとして空気ばねを用いることが一般的である。空気ばねは、半導体製造装置のような重量物を支持するのに十分な推力を容易に発生できるからである。従来技術にみられる典型的な除振装置の構成を図５に示す。

【０００４】図５に示した従来技術にみられる除振装置の動作を説明する。露光用ＸＹステージなどの精密機器を搭載する除振台１は空気ばね５によって設置床１００から浮上支持されている。空気ばね５で除振台１を浮上支持することにより、除振台１を設置床１００から振動絶縁することができる。空気ばね５の圧力は空気弁４によって調整される。空気弁４は図６に示すように給気ポート６１、排気ポート６２および出力圧力ポート６３の３ポートを備えたノズルフラッパ型が一般的である。出力圧力は空気弁駆動量（フラッパ開度）に応じて変化する。空気弁駆動量と出力圧力の特性を図７に示す。図７のように、空気弁駆動量－出力圧力特性は非直線的でヒステリシスがあり、非線形性が強い。また、一般に空気ばねは応答が遅く圧力の定位性が悪い。そこで、空気弁４を用いて空気ばね５の圧力を調整する場合は、空気ばね５の圧力を計測しその計測信号に応じて空気弁駆動量を調整するというように、圧力のフィードバック制御を行なうことが多い。

【０００５】図５において、圧力センサ３は空気ばね５の圧力を計測する。圧力目標生成器１１は、空気ばね５が除振台１を浮上支持した定常状態の圧力に対する目標値を出力する。圧力補償器１２は、後述する変位補償器９および加速度補償器１０の出力信号と圧力目標生成器１１の出力信号との和に対して、圧力センサ３の出力信号が一致するような補償を行なう。パワー増幅器１３は圧力補償器１１の出力に応じて空気弁４にパワーを供給し、空気弁４を駆動する。このような圧力のフィードバック制御によって、空気ばね５の圧力を所望の値に制御する。

【０００６】また、変位センサ２は除振台１および空気ばね５の変位を計測する。変位目標生成器７は除振台１および空気ばね５の浮上変位に対する目標値を出力する。変位補償器９は変位目標生成器７の出力信号と変位センサ２の出力信号の差がゼロとなるような補償を行なう。これによって除振台１および空気ばね５の浮上変位を一定に保持する。加速度センサ６は除振台１の振動を

計測する。加速度補償器１０は加速度センサ６の出力信号に補償を行ない、加速度の負帰還系を形成する。これによって除振台１に発生する振動を抑制する。

【０００７】

【発明が解決しようとする課題】空気ばねを用いた除振装置では、空気弁の非線形特性を補正するため、そして空気ばねの圧力の定位性を改善するため、空気ばねの圧力を圧力センサで計測しその出力信号に応じて空気弁を駆動する、いわゆる圧力のフィードバック制御が行なわれている。ところが、空気ばねに対して圧力のフィードバック制御を行なうと、空気ばねの剛性が低下して除振台の振動が増大してしまうという問題点があった。空気ばねが浮上支持する除振台は、除振台に作用する重力と空気ばねからの支持力とが一致する状態で平衡している。空気ばねからの支持力は、空気ばねと除振台の接触部における有効受圧面積に空気ばねの圧力を乗じて定まるものである。半導体製造装置において除振台に載置される露光用ＸＹステージの駆動反力など、何らかの外乱力のため除振台に振動が発生した場合、本来、除振台の変位に応じて空気ばねの容積が変化し空気ばねの圧力が変わるので、除振台を平衡状態へ戻すような、変位に比例した平衡状態への復元力が空気ばねから除振台に作用する。これが空気ばねの剛性である。圧力のフィードバック制御は空気ばねの圧力を一定に保持するように機能するので、除振台の変位と空気ばねの容積変化が生じても空気ばねの圧力は変化しない。すなわち、空気ばねの剛性が低下して、除振台に平衡状態への復元力が作用しない。よって、圧力のフィードバック制御を行なうと、除振台に外乱力など何らかの要因で振動が発生した場合、空気ばねの剛性低下のため除振台の振動が増大してしまうという問題があった。従来の除振装置において、圧力のフィードバック制御による空気ばねの剛性低下を解決しているものは見受けられない。

【０００８】本発明はこのような事情を考慮してなされたものである。すなわち、本発明の目的は、空気ばねの剛性低下を招くことなく空気ばねの圧力のフィードバック制御を行なうことができる除振装置を提供することにある。

【０００９】

【課題を解決するための手段】上記目的を達成するために、本発明による除振装置は、除振台と、前記除振台を支持する空気ばねと、前記空気ばねの圧力を調整する空気弁と、前記空気ばねの圧力を計測する圧力センサと、前記除振台の変位および前記空気ばねの変位を計測する変位センサと、前記除振台の振動を計測する加速度センサと、前記加速度センサの出力信号に補償を施し加速度の負帰還系を形成する加速度補償器と、前記除振台および前記空気ばねの変位に対する目標値を出力する変位目標生成器と、前記変位目標生成器の出力信号と前記変位センサの出力信号との差信号に補償を施し前記除振台および前記空気ばねの変位を制御する変位補償器と、ローカットフィルタと比例ゲイン要素を有する剛性補償器であり、かつ、前記変位センサの出力信号に補償を施し空気ばねの剛性を制御する剛性補償器と、前記空気ばねの圧力に対する目標値を出力する圧力目標生成器と、前記加速度補償器および前記変位補償器および前記剛性補償器および前記圧力目標生成器の出力信号と前記圧力センサの出力信号に補償を施し前記空気ばねの圧力を制御する圧力補償器と、前記圧力補償器の出力信号に応じて前記空気弁を駆動するパワー増幅器を有することを特徴とする。

【００１０】また、本発明によるデバイス製造装置は、前記除振装置を有することを特徴とする。デバイス製造装置としては、ＩＣやＬＳＩ等の半導体チップを製造するための半導体製造装置等がある。

【００１１】

【作用】空気ばねは露光用ＸＹステージ等の精密機器を搭載する除振台を浮上支持する。空気弁は空気ばねの圧力を調整する。圧力センサは空気ばねの圧力を測定する。圧力目標生成器は空気ばねが除振台を浮上支持した定常状態の圧力に対する目標値を出力する。圧力補償器は、剛性補償器および変位補償器および加速度補償器の出力信号と圧力目標生成器の出力信号との和に対して、圧力センサの出力信号が一致するような補償を行なう。パワー増幅器は圧力補償器の出力に応じて空気弁にパワーを供給し、空気弁を駆動する。

【００１２】変位センサは除振台の変位および空気ばねの浮上変位を計測する。変位目標生成器は除振台の変位および空気ばねの変位に対する目標値を出力する。変位補償器は除振台が所望の浮上位置へ定位するように変位目標生成器の出力信号と変位センサの出力信号との差がゼロとなるような補償を行なう。加速度センサは除振台に固定されており、除振台に生じる振動を加速度信号として計測する。加速度補償器は加速度センサの出力信号に補償を行ない、加速度の負帰還を形成する。これによって除振台へダンピングを付与する。

【００１３】ローカットフィルタと比例ゲイン要素を有する剛性補償器は、除振台および空気ばねへ剛性を付与するように、変位センサの出力信号に補償を行なう。空気ばねが浮上支持する除振台は、除振台に作用する重力と空気ばねからの支持力とが一致する状態で平衡している。半導体製造装置において除振台に載置される露光用ＸＹステージの駆動反力など、何らかの外乱力のため除振台に振動が発生した場合、剛性補償器はアクチュエータである空気ばねを介して除振台の変位あるいは空気ばねの変位に比例した平衡状態への復元力が除振台へ作用するように機能する。

【００１４】このように、圧力のフィードバック制御を行なっても、剛性補償器の機能により空気ばねの剛性低下は生じない。圧力のフィードバック制御は空気弁の非

線形特性を補正し空気ばねの圧力の定位性を改善する。同時に、空気ばねの剛性低下は生じないので、振動抑制性能の良好な除振装置を実現することができる。

【００１５】

【実施例】本発明による除振装置の実施例について、図面に基づき詳細に説明する。図１は本発明の一実施例に係る除振装置の構成を示す。同図において、除振台１は空気ばね５によって浮上支持されている。空気ばね５は除振台１を浮上支持する支持脚であると同時に、除振台１の振動を抑制するため空気ばね５の圧力変化により除振台１へ制振力を作用させるアクチュエータでもある。空気ばね５の圧力は空気弁４によって調整される。

【００１６】圧力のフィードバック制御は次のように実現されている。圧力センサ３は空気ばね５の圧力を計測する。圧力目標生成器１１は空気ばね５が除振台１を浮上支持した定常状態の圧力に対する目標値を出力する。圧力補償器１２は、後述する剛性補償器８および変位補償器９および加速度補償器１０の出力信号と圧力目標生成器１１の出力信号との和に対して、圧力センサ３の出力信号が一致するような補償を行なう。パワー増幅器１３は圧力補償器１１の出力に応じて空気弁４にパワーを供給し、空気弁４を駆動する。このような圧力のフィードバック制御によって、空気ばね５の圧力を所望の値に制御する。

【００１７】変位センサ２は除振台１の変位および空気ばね５の変位を計測する。ここでいう空気ばね５の変位とは空気ばね５のストロークのことであり、除振台１の変位と同一である。変位目標生成器７は除振台１の変位および空気ばね５の浮上変位に対する目標値を出力する。変位補償器９は除振台１が所望の浮上位置へ定位するように変位目標生成器７の出力信号と変位センサ２の出力信号との差がゼロとなるような補償を行なう。変位補償器９は、その入力信号の積分で空気ばね５の圧力が制御されるように設計するのが常套手段である。変位目標生成器７の出力信号に対して除振台１の変位をオーバーシュートすることなくすみやかに収束させるためである。

【００１８】加速度センサ５は除振台１に固定されており、除振台１に生じる振動を加速度信号として計測する。加速度補償器１０は加速度センサ６の出力信号に補償を行ない、加速度の負帰還を形成する。前述したように、変位補償器９はその入力信号の積分で空気ばね５の圧力が制御されるように設計しているので、加速度補償器１０が加速度センサ６の出力に比例した補償値を生成し、この補償値を変位補償器９へ入力すれば、加速度の＊積分、すなわち速度に比例した制振力を除振台１に作用させることができる。これによって除振台１へダンピングを与え、除振台１に生じる振動を効果的に抑制している。

【００１９】ローカットフィルタ１４と比例ゲイン要素１５を有する剛性補償器８は、除振台１および空気ばね５へ剛性を付与するように、変位センサ２の出力信号に補償を行なう。空気ばね５が浮上支持する除振台１は、除振台１に作用する重力と空気ばね５からの支持力とが一致する状態で平衡している。半導体製造装置において除振台１に載置される露光用ＸＹステージの駆動反力など、何らかの外乱力のため除振台１に振動が発生した場合、剛性補償器８はアクチュエータである空気ばね５を介して除振台１の変位あるいは空気ばね５の変位に比例した平衡状態への復元力が除振台１へ作用するように機能する。これによって、除振台１および空気ばね５に剛性を与え、除振台１に生じる振動を効果的に抑制している。

【００２０】剛性補償器８と変位補償器９はどちらも変位センサ２の信号を入力としているが、これまで説明したように両者の機能は全く異なっている。剛性補償器８は除振台１の変位あるいは空気ばね５の変位に比例した平衡状態への復元力を除振台１へ作用させるように機能する。これによって、前述した圧力のフィードバックによる空気ばね５の剛性低下を回避することができる。変位補償器９は除振台１が所望の浮上位置へオーバーシュートすることなく定位するように、変位目標生成器７の出力信号と変位センサ２の出力信号との差の積分で除振台１へ力が作用するように機能する。したがって、変位補償器９の機能によって空気ばね５へ剛性を付与することはできない。剛性とは変位に比例した平衡状態への復元力のことだからである。

【００２１】以下、剛性補償器８の動作をさらに詳しく説明する。図２は除振台１、空気弁４および空気ばね５からなる部分の動力学モデルを示す。除振台１は質量Ｍの質量要素としてモデル化できる。その変位をｘ、除振台１に作用する外乱力をｆ、また除振台１が空気ばね５から力を受ける部分の有効受圧面積をＡとする。空気弁４は空気弁駆動量ｕに応じて空気の流入流出流量と空気ばね５の圧力ｐを調整する。圧力ｐは平衡状態からの変動量であるとして、図２より除振台１の運動に関して（１）式が得られる。また空気ばね５の圧力に関して（２）式が成立する。

【００２２】

【数１】

$$M\frac{d^2}{dt^2}x = Ap + f \qquad (1)$$

$$\frac{d}{dt}p + \omega p = G_q\ u - G_v\frac{d}{dt}x \qquad (2)$$

【0023】(2)式において、左辺の圧力pに掛かる係数ωは空気ばね5の機械的パラメータから定まる物理量である。また、右辺の空気弁駆動量uに掛かる係数G_qは空気弁4の圧力ゲインである。同じく右辺で除振台1の変位xを含む項は変位xによって空気ばね5の圧力pが変化することを表わしており、G_vはその影響係数である。(1)式および(2)式をラプラス変換することにより、図2の動力学モデルを数学的に示した図3のブロック線図が得られる。図3において、記号sはラプラス演算子を表わす。図3より、入力を空気弁駆動量uおよび外乱力f、出力を除振台1の変位xとした入出力式は(3)式のようになる。(3)式においては、左辺のAG_v s／(s+ω)が空気ばね5の剛性を表わしている。

【0024】

【数2】

$$\left(Ms^2 + AG_v\frac{s}{s+\omega}\right)x = f + \frac{1}{s+\omega}AG_q\,u \qquad (3)$$

【0025】本実施例による除振装置の動作を数学的に示したブロック線図が図4である。図4は剛性補償器8の動作を説明するのに必要十分な要素のみを示しており、変位補償器9、加速度補償器10など他の構成要素は省略している。図4において圧力補償器12は比例演算器でありそのゲインをGとする。また剛性補償器8の伝達関数をG_kとする。入力を外乱力f、出力を除振台1の変位xとした図4の入出力式は(4)式のとおりである。

【0026】

【数3】

$$\left(Ms^2 + AG_v\frac{s}{s+\omega+G_q G} + AG_v\frac{1}{s+\omega+G_q G}\frac{G_q GG_k}{G_v}\right)x = f \qquad (4)$$

【0027】もしも剛性補償器8がなくてG_k=0であったとしたら、(4)式の入出力式は(5)式のようになる。この場合、空気ばね5の剛性を表わす剛性項は(5)式の左辺よりAG_v s／(s+ω+G_q G)であるが、圧力補償器12のゲインGが剛性項の分母にあるので、ゲインGが大きいほど剛性項は小さくなる。つまり、圧力のフィードバックループのゲインGを大きくするほど空気ばね5の剛性は低下することが(5)式からわかる。

【0028】

【数4】

$$\left(Ms^2 + AG_v\frac{s}{s+\omega+G_q G}\right)x = f \qquad (5)$$

【0029】剛性補償器8は圧力のフィードバック制御による空気ばね5の剛性低下を回避するように機能する。(4)式からわかるように、剛性補償器8の動作によって、空気ばね5の剛性項はAG_v s／(s+ω+G_q G)+AG_v／(s+ω+G_q G)×G_q GG_k／G_vとなっている。すなわち、剛性補償器8の伝達関数G_kを大きくとるほど剛性項も大きくなるので、空気ばね5にとって必要な剛性が確保できる。伝達関数G_kは、具体的には次のように設計すればよい。まず、圧力のフィードバック制御を行なわない場合、空気ばね5の剛性項は(3)式左辺よりAG_v s／(s+ω)であった。伝達関数G_kは、本発明による除振装置の入出力式である(4)式の剛性項がこれに一致するように設計する。(3)式と(4)式を比較すれば、剛性補償器8の伝達関数G_kは(6)式のように定まる。

【0030】

【数5】

$$G_k = \frac{s}{s+\omega}\,\frac{G_v(\omega+G_q G)}{G_q G} \qquad (6)$$

【0031】(6)式で定めた伝達関数G_kを本実施例による除振装置の入出力式である(4)式に代入すると(7)式が得られる。(7)式の左辺と、圧力のフィードバック制御を行なわない場合の入出力式である(3)式の左辺は全く同一である。剛性補償器8の動作によって、圧力のフィードバック制御を行なわない場合と全く同一な空気ばね5の剛性を確保できることがわかる。また、(6)式で示される剛性補償器8の伝達関数G_kは、ローカットフィルタを表わす伝達関数s／(s+ω)と比例ゲインG_v(ω+G_q G)／G_q Gとの直列結合で構成されている。本実施例による除振装置は、剛性補償器8がローカットフィルタ14と比例ゲイン要素15を有することを特徴としている。

【0032】

【数6】

$$\left(Ms^2 + AG_v\frac{s}{s+\omega}\right)x = f \qquad (7)$$

【0033】このように、剛性補償器8の動作によって空気ばね5の剛性低下を回避することができるので、本実施例による除振装置は好適な振動抑制性能を実現している。なお、本発明による除振装置は図1に示した実施形態に限定されるものではない。空気ばねの剛性低下を生じることなく空気ばねの圧力のフィードバック制御を行なうことができる除振装置であるという本発明の本質は、除振台の形状やそれを支持する空気ばねの台数と配

置などを問わず実施できる。また、本発明による除振装置を有する半導体製造装置は、逐次駆動型、走査型のいずれにおいても実現できる。

【0034】これまで用いた数式記号を次にまとめて列記する。

M：除振台１の質量

A：空気ばね５の有効受圧面積

x：除振台１の変位

p：空気ばね５の圧力

u：空気弁駆動量

f：除振台１に作用する外乱力

ω：空気ばね５の機械的パラメータから定まる物理量

G_o：空気弁４の圧力ゲイン

G_v：除振台１の変位xから空気ばね５の圧力pへの影響係数

G：圧力補償器１２が比例演算器であるときのゲイン

G_k：剛性補償器８の伝達関数

【0035】

【デバイス生産方法の実施例】次に上記説明した除振装置を有する露光装置を利用したデバイスの生産方法の実施例を説明する。図８は微小デバイス（ＩＣやＬＳＩ等の半導体チップ、液晶パネル、ＣＣＤ、薄膜磁気ヘッド、マイクロマシン等）の製造のフローを示す。ステップ１（回路設計）ではデバイスのパターン設計を行なう。ステップ２（マスク製作）では設計したパターンを形成したマスクを製作する。一方、ステップ３（ウエハ製造）ではシリコンやガラス等の材料を用いてウエハを製造する。ステップ４（ウエハプロセス）は前工程と呼ばれ、上記用意したマスクとウエハを用いて、リソグラフィ技術によってウエハ上に実際の回路を形成する。次のステップ５（組み立て）は後工程と呼ばれ、ステップ４によって作製されたウエハを用いて半導体チップ化する工程であり、アッセンブリ工程（ダイシング、ボンディング）、パッケージング工程（チップ封入）等の工程を含む。ステップ６（検査）ではステップ５で作製された半導体デバイスの動作確認テスト、耐久性テスト等の検査を行なう。こうした工程を経て半導体デバイスが完成し、これが出荷（ステップ７）される。

【0036】図９は上記ウエハプロセスの詳細なフローを示す。ステップ１１（酸化）ではウエハの表面を酸化させる。ステップ１２（ＣＶＤ）ではウエハ表面に絶縁膜を形成する。ステップ１３（電極形成）ではウエハ上に電極を蒸着によって形成する。ステップ１４（イオン打込み）ではウエハにイオンを打ち込む。ステップ１５（レジスト処理）ではウエハに感光剤を塗布する。ステップ１６（露光）では上記説明した除振装置を有する露光装置によってマスクの回路パターンをウエハに焼付露光する。ステップ１７（現像）では露光したウエハを現像する。ステップ１８（エッチング）では現像したレジスト像以外の部分を削り取る。ステップ１９（レジスト剥離）ではエッチングが済んで不要となったレジストを取り除く。これらのステップを繰り返し行なうことによって、ウエハ上に多重に回路パターンが形成される。本実施例の生産方法を用いれば、従来は製造が難しかった高集積度のデバイスを低コストに製造することができる。

【0037】

【発明の効果】以上説明したように、本発明によれば、空気ばねの剛性を低下させずに空気ばねの圧力のフィードバック制御を行なうことができる除振装置を提供することができる。本発明による除振装置においては、圧力のフィードバック制御が空気弁の非線形特性を補正し、空気ばねの圧力の定位性を改善する。同時に、従来技術で問題となっていた空気ばねの剛性低下は生じないので、好適な振動抑制性能を実現することができる。

【図面の簡単な説明】

【図１】　本発明の一実施例に係る除振装置の構成図である。

【図２】　除振台と空気ばねの動力学モデルを示す図面である。

【図３】　除振台と空気ばねの動力学モデルを数学的に示す図面である。

【図４】　本発明による除振装置の動作を数学的に示す図面である。

【図５】　従来技術による除振装置を示す図面である。

【図６】　空気弁の構造を示す図面である。

【図７】　空気弁の特性を示す図面である。

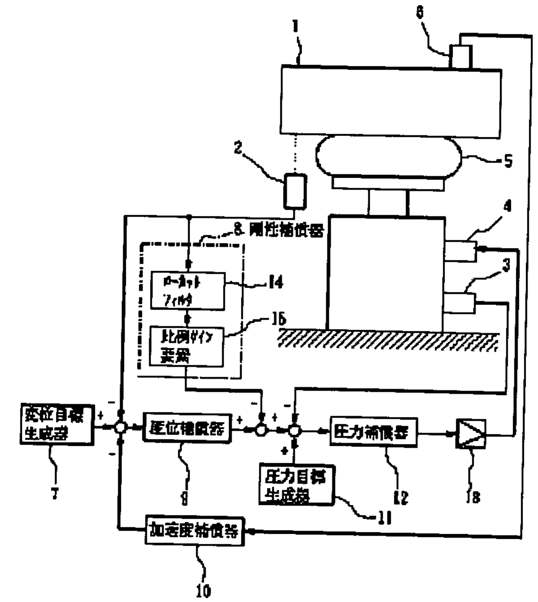
【図８】　微小デバイスの製造の流れを示す図である。

【図９】　図８におけるウエハプロセスの詳細な流れを示す図である。

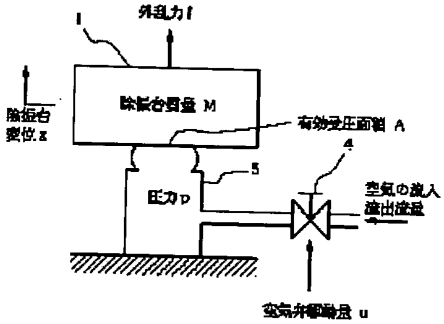
【符号の説明】

１：除振台、２：変位センサ、３：圧力センサ、４：空気弁、５：空気ばね、６：加速度センサ、７：変位目標生成器、８：剛性補償器、９：変位補償器、１０：加速度補償器、１１：圧力目標生成器、１２：圧力補償器、１３：パワー増幅器、１４：ローカットフィルタ、１５：比例ゲイン要素。

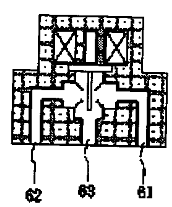
【図1】



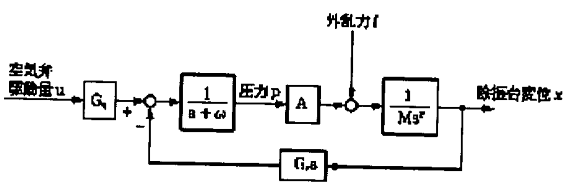
【図2】



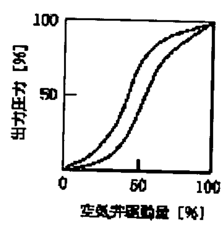
【図6】



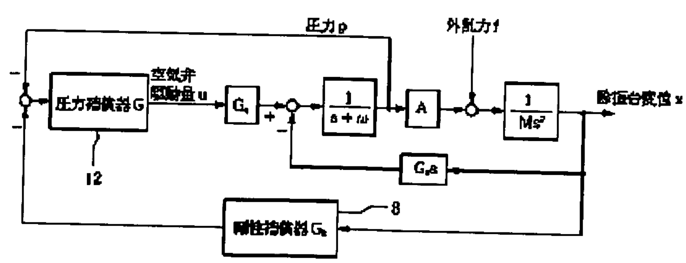
【図3】



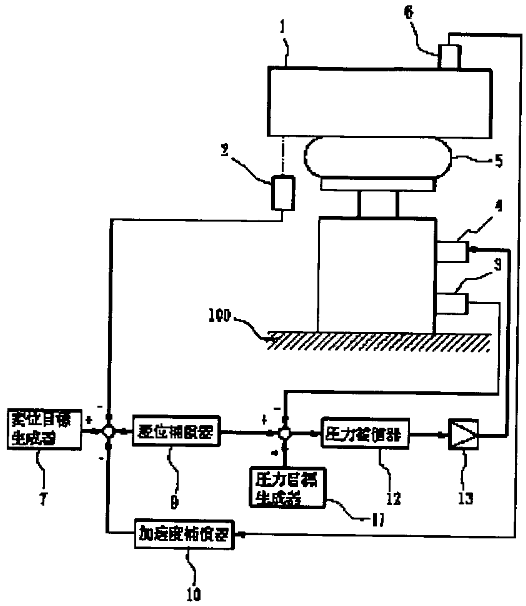
【図7】



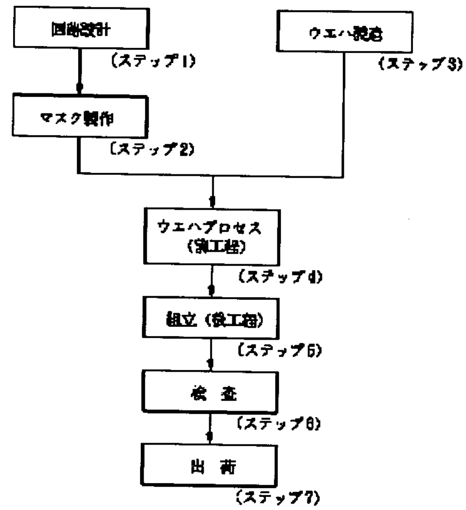
【図4】



【図５】

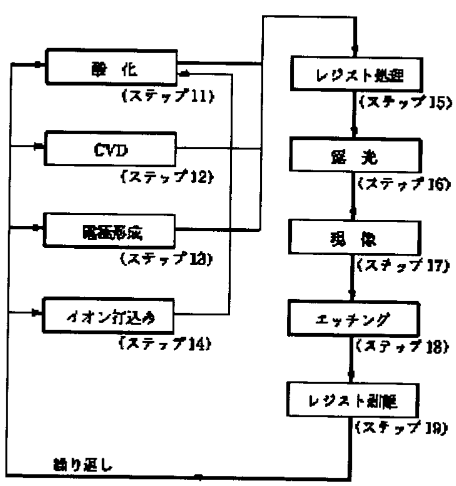


【図８】



半導体デバイス製造フロー

【図９】



ウエハプロセス

フロントページの続き

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